LIMITED USE OF REMOTELY SENSED DATA FOR CROP CONDITION MONITORING AND CROP YIELD FORECASTING IN NASS

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EXECUTIVE SUMMARY

This paper discusses the limited use that NASS has made of remotely sensed data for crop condition monitoring and crop yield forecasting and estimation. It also highlights obstacles that need to be overcome for more extended use of remotely sensed data for these purposes. The major purpose of this paper is to counter some common misconceptions related to the use of remotely sensed data for crop condition monitoring and crop yield forecasting and estimation. When there is a wealth of ground based (objective crop plant and fruit counts and fruit weights) and farmer reported data, such as in the United States, it is difficult for space based remote sensing to compete for large area statistical yield inventories. Joint research, however, continues between NASS and the Agricultural Research Service to try to overcome some of the obstacles.

TIMELINESS

The basic difference between using remote sensing for acreage versus for crop condition and yield has to do with timeliness. The paper on crop area estimation clarified that remote sensing data are not available early enough to replace NASS present early season estimates but can provide important information for improving planted area estimates at the end of the season. This is because total crop area does not change much throughout the season, so 1-2 satellite "looks" during the growing season are sufficient for major crops. However, crop conditions change quickly so timely repeat coverage throughout the season is needed to monitor crop condition and to approximate yields.

CROP CONDITION MONITORING

The current major use by NASS of remotely sensed data for crop condition monitoring is the use of a bi-weekly composite of the normalized difference vegetation index (NDVI) from the Advanced Very High Resolution Radiometer (AVHRR) on polar orbiting weather satellites operated by the National Oceanic and Atmospheric Administration (NOAA). The EROS Data Center of the U.S. Geological Survey archives the AVHRR data and creates a bi-weekly composite of the NDVI. NASS procures the bi-weekly composites, compares the images over time, and links them to the Weekly Crop and Weather Report issued weekly by NASS and the Joint Agricultural Weather Facility (JAWF) of USDA and NOAA.

Instead of just presenting the NVDI composites, NASS maps the relationship between current and previous year levels on a data point by data point basis, expressing the percentage relationships in several ranges, as color themes. A second comparison, which is often more helpful, is comparing present NDVI levels to median values from the corresponding period for all years in the data archives, for which the NDVI data is considered comparable. Besides U.S.

level maps with State boundaries overlaid, NASS provides enlarged map images, which normally cover one to two states, with county boundaries of areas known to be of particular current interest. The current NASS web site http://www.nass.usda.gov/research /avhrr/avhrrmnu.htm allows users to zoom into areas of interest from the national images. From the research home page, select Vegetation Condition to see images and comparisons since 1995. In 2000 images were removed as an aging satellite had orbit problems. In 2002, images from 2002 and 2001 will be displayed from a newer satellite.

The NDVI images have proven especially valuable in providing a spatially complete view of some major events in U.S. crop production over the last several years. One was the massive 1993 flood in the Midwest with resulting drops in corn and soybean acreages and yields. The effects of the long, dry, cold and windy winter and dry, early spring of 1995/96 in the southern Great Plains, which resulted in the abandonment of several million acres and drops in winter wheat yields, were easily seen on both the NDVI image comparisons from year to year and to the median. More recently, the 1999 drought conditions in Texas and the Mid-Atlantic region were very apparent on the images as well as the current 2002 drought, affecting winter wheat again, in portions of the western Plains. AVHRR images were part of the briefing material used by the Chairperson of the NASS Agricultural Statistics Board for the May 10, 2002 briefing for the Secretary of Agriculture and the Chief Economist of USDA.

Both NVDI images and conventional data have some strengths and some limitations for crop condition monitoring. The following paragraphs provide brief descriptions of those characteristics.

AVHRR NDVI data have 1 square kilometer resolution (about 250 acres) which is both a strength and a limitation. This resolution can provide substantial detail when viewing a large area such as a state, region, or country level. The U.S. is covered daily by the AVHRR sensor, allowing multiple, timely looks at specific areas. However, the resolution cannot routinely provide crop specific information because of varying crops in the same region, field size limitations, and alternating crop and fallow field patterns. There are events, such as the 1993 flood and the severe drought in the southern Great Plains in 1995/96, that provided valuable crop condition interpretations over large areas because a large percentage of all vegetation was impacted negatively.

The most common event captured sufficiently by AVHRR NDVI is drought over a large area of rain-fed crops or pasture/grassland. Late in the crop season, it can also give a good view of areas susceptible to early frost damage, if crop progress is lagging. If the imagery is relatively free from atmospheric interference and has no apparent sharp scene lines, the images do an excellent job of showing the extent and location of widespread vegetative stress. These large area views of such events are quite informative as they provide a complete spatial view, which is virtually impossible to obtain with ground survey data. Policy makers, such as the Secretary of Agriculture and USDA Chief Economist, have appreciated obtaining these image views when the situation was appropriate.

The major limitations to NDVI are atmospheric interference and the fact that, even with the 250-acre pixel size, one does not get a crop specific reading. Atmospheric interference comes in

the form of clouds, haze, smoke, etc. Algorithms can remove many but not all contaminated pixel values. The algorithms either remove only the very obvious cloud/snow-covered pixels or run the risk of eliminating some valid pixel values. Bi-weekly composites often have some pixels, usually near known cloud-covered pixels, with artificially low NDVI values which implies they were contaminated by atmosphere but made it through the screening algorithm. The trained eye is the best defense in recognizing and removing those pixels, which makes the development of appropriate metadata challenging.

The conventional Weekly Crop and Weather Report, also has strengths and weaknesses. The strength is the "expert opinion" of the network of weekly reporters such as agricultural extension agents who are quite knowledgeable about crop production in their local areas. Timely, but subjective, crop stage and condition observations are acquired and summarized at the state level. The data are quantitative but, given the subjective nature, are perhaps over-quantified when reported to one percentage point values. These data are only valuable when aggregated at the State, or in some cases, Agricultural Statistics District levels but they do provide timely crop specific interpretations and information.

CROP YIELD FORECASTING AND ESTIMATION

NASS uses two major survey techniques for crop yield forecasting and estimation. The more common is the use of list or multiple frame-based sample surveys of farm operators. Farmers selected in the statistically based sample are asked to report their final harvested yield or their best evaluation of potential yield, based on current conditions, during the forecast season. The second is objective yield surveys which utilize plant counts and fruit measurements from random plots in selected fields. Because of the high cost of in-field observations, objective yield surveys are normally used only in major producing States. Data from multiple years are used to build models that relate pre-harvest counts and measurements to the final post harvest yield. For example, by August 1 there is current year plant population information and an early indication of corn ear population but no current information on final corn ear weight. Models normally have two components: one for ear population based upon current observations with some forecasting and corn ear weight based upon forecasting methods. As the crop season progresses, current season information on size and weight of corn ears becomes available and is used in the forecast. The Agricultural Statistics Board, composed of statisticians permanently assigned and rotating State office statisticians review indications from both surveys and the State office recommendations to set official forecasts and estimates at the State, regional, and national levels. There currently is no direct quantitative use of weather data or soils data in the operational program to forecast or estimate crop yields. Research efforts have studied the use of additional variables, but so far only weather data showed very marginal gains. In some cases weather variables, such as early season rainfall at the State level, were tried in the operating program, but later dropped. Of course, both the objective yield data and the farmer reported data indirectly reflect, to some degree, weather and soils effects as well as plant diseases, plant pests, excessive weed growth and other effects as well, such as new varieties.

Space-borne remotely sensed data, such as AVHRR or French SPOT VEG or MODIS NDVI's, can provide a crop growth profile during a crop season. However, at best, it is measuring biomass or leaf area index but not directly fruit health, size, or weight. To date, our research

experience shows that AVHRR-based crop yield estimates are not nearly as precise as NASS's existing survey system for U.S. crop yield data. However, in areas with no survey or ground data systems, AVHRR-based data can provide limited year to year interpretations of changes in yield levels. One possible use of such data by NASS might be to spread statistically based ground survey results to lower levels of aggregation, such as counties. NASS is conducting joint research with USDA Agricultural Research Service's Remote Sensing and Modeling Laboratory in Beltsville, Maryland to use the major strength of remotely sensed data, spatial completeness and detail. In addition, this research is aimed at evaluating new sensors that are similar to AVHRR, such as the new sensor, Moderate Resolution Imaging Spectro-Radiometer (MODIS), on the TERRA and ACQUA Earth Observing Systems launched by the National Aeronautics and Space Administration (NASA). MODIS is similar in nature to AVHRR, with very good temporal frequency, but also has improved spatial resolution and spectral band coverage. The current issue with MODIS for NASS applications, is lack of real time delivery of composite data at present. If real time delivery of composite (bi-weekly) MODIS data becomes a reality, then it is likely MODIS will replace AVHRR for timely crop condition monitoring purposes.